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THE AMERICAN
METEOROLOGICAL JOURNAL.

VOL. IV. ANN ARBOR, APRIL, 1888. No. 12.

ORIGINAL ARTICLES.

THE METEOROLOGICAL SERVICE IN PRUSSIA.

[CONTINUED.]

BY A. LAWRENCE ROTCH,

Member of the German Meteorological Society, and Fellow of the Royal (London) Meteorological Society.

THE ROYAL PRUSSIAN METEOROLOGICAL INSTITUTE.

History and Organization.—Prussia was slow to follow the other states in the establishment of a system of stations, Baden and Bavaria having a good system for the observation of meteorological phenomena at the end of the last century, while Württemberg and Saxe Weimar commenced in 1821. The Royal Prussian Meteorological Institute was founded as a part of the Royal Statistical Bureau in 1847, and Dr. Mahlmann given its direction with a budget of 9,000 marks. He managed it admirably, himself inspecting the stations and instruments and choosing the observers mostly from the high school teachers. There were at first about 35 observers, who were paid 150 marks yearly. The hours of observations adopted, after much discussion, were 6, 2 and 10, and these were till 1887 the most used in North Germany and Austria. The instruments were chiefly constructed by Greiner, of Berlin, but Pistor and Martin made a part of the barometers. The forms containing the observations and the formulæ for their reduction were used with slight alterations until the adoption of

the universal ones recommended by the Roman Congress in 1879.

Professor H. W. Dove, who succeeded Mahlmann, brought out in 1851 the first volume of the observations which have since been published each year with the *Prussian Statistics.* Within the first ten years some of the smaller states had established meteorological services in connection with the Prussian. Dove died in 1879 and was replaced by Professor Arndt, under whom the recommendations of the Roman Congress regarding the metric system and forms of publications were followed, and new instruments procured, as fast as the budget of 27,000 marks would permit. Dr. Hellmann assumed the management of the Institute on the death of Arndt in 1882. The changes which he brought about were chiefly the increase in the number of secondary and rain stations and the establishment of a station on the Schneekoppe, Prussia's highest mountain, and two other high level stations. It would have been impossible to have reduced and published the observations with the scanty appropriation, had it not been for the aid of the Statistical Bureau.

A reorganization of the Institute was already proposed by Dove while living, but it was not until 1886 that the plan was confirmed by the State, which appropriated 44,000 marks for the first cost and 73,000 marks for current expenses. The scheme for reorganization, for which five years are allowed, is as follows: To insure stability of stations and observers, these are, so far as practicable, to be in public buildings. Vacancies in the existing net of stations are to be filled and some 2,000 rain stations established. The Central Institute is to be not only, as heretofore, the headquarters of the stations to receive and publish their observations, but also a first-class observatory. As, however, the conditions suited to a central institute and an observatory are different, since the former must be as accessible as possible, and the latter away from present or future disturbing influences, it is proposed to have the magnetic and meteorological observatory erected on the Telegraphenberg in Potsdam, near the Astro-physical Observatory, while the Central Institute

is to be in Berlin. It is intended, eventually, to have two other first-class stations, one in the west, the other in the east of the kingdom, connected with existing observatories, to lessen the cost of new buildings. For the present no weather telegraphy will be attempted.

The Central Institute is temporarily situated in the former Bau-Academie (Schinkelplatz 6) and has arrangements for testing instruments and experimenting, which later will be done at Potsdam. The director of the Institute, who is likewise professor in the newly created chair of meteorology in the University of Berlin, is Professor W. von Bezold. The other officials are Drs. Hellmann, Sprung and Assmann, with three assistants, a secretary, and some clerks.

The Stations and Methods of Observation.—The stations of the Institute embrace the non-Prussian stations in Mecklenburg, Oldenburg, Brunswick, and the small Saxon states which send their observations either direct, or through some local authority. The number of stations of the second, third and fourth order (rain stations) which report to the Institute is about 430. The Institute has not yet any first order stations belonging to it, and though some of the Seewarte and other reporting stations are of the first order, they are classified with the second order stations of the Institute, which include the mountain stations of the Schneekoppe (1,603 m.), Schneegruben Baude (1,490 m.), Glatzer Schneeberg (1,217 m.), and Brocken (1,141 m.) Those of the Schneekoppe and Brocken were described by the writer in No. 10, Vol. II, of the JOURNAL. The Brocken observations have of late been irregular, owing to frequent changes of observers.

All stations of the second order make observations at 7, 2 and 9 o'clock, and enter them on a schedule which contains data as to the height of the instruments above sea or ground and their instrumental correction. The schedule is divided into decades, and has the following headings:

(1) Actual barometer and attached thermometer for three observations, barometer reduced to 0° and daily mean.

(2) Extreme temperatures (max. and min.) and their difference, or the daily range.

(3) Tri-daily observations of dry bulb thermometer and daily mean. The mean temperature is determined by using the formula: $\frac{1}{4}(7+2+2.9)$. For the other elements the arithmetical mean is used.

(4) Tri-daily wet bulb observations. From these:

(5) Absolute humidity and

(6) Relative humidity for the three observations, with daily means.

(7) Cloudiness at three observations and daily mean, estimated on scale of 0 to 10.

(8) Tri-daily observations of cloud direction with especial reference to the cirrus.

(9) Tri-daily direction and force of wind (Beaufort scale, 0 to 12).

(10) Precipitation, amount, kind and time.

(11) Remarks.

Instructions, with the explanation of the international symbols for hydrometeors are given at the bottom of the sheet; also a monthly summary containing the principal results of the observations and five-day means of the temperature. The tables for calculating the humidity are those of Jelinek, and for reducing the barometer tables on cards are supplied. The detailed instructions for filling out the schedule of observations are contained in a small pamphlet issued by the Institute.

The third order stations make one, two or three observations daily, and enter them according to this schedule:

(1) Air temperature: max. min. $\frac{1}{2}$ (max. and min.).

(2) Precipitation: amount, kind and time.

(3) Clouds: four spaces for tri-daily observations and the mean, and for

(4) Direction and force of wind, three similar spaces.

(5) Remarks.

There is a monthly summary of these observations.

The rain stations observe generally at 8 A. M., and record on a post card. On the back of the card are data concerning the position of the station and the height of the gauge. The amount, kind and time of precipitation is expressed in the international symbols.

Some 300 thunder-storm observers who formerly reported to Dr. Assmann now report to the Institute. They have no instruments, but note the time, character, direction of motion, etc., of the storm in a book carried with them, which data are sent on post cards, after each storm, to Berlin. The country is divided into squares by numbered parallels and meridians and the position of the station fixed by these numbers. The observations at each station are plotted for every storm, and isobrontal lines and the path of the storm drawn. The discussion of these observations, formerly published by Dr. Assmann, will now appear in the publications of the Institute.

All the schedules are sent to the Institute at the end of the month. The majority of the observers, who belong to the educated class, such as school teachers, etc., reduce their observations so that only a few of the schedules require re-calculation. Statistics show that on the average each observer continues about eight years. They receive about 225 marks a year, and the instruments are generally loaned them by the Institute.

The instrumental outfit of the different classes of stations is as follows: The second order stations have barometers, psychrometers, (sometimes hair hygrometers also), maximum and minimum thermometers, rain and snow gauges and wind vanes. The third order stations have maximum and minimum thermometers, with check thermometers, rain and snow gauges. The fourth order stations have only rain and snow gauges. The compensated cistern barometers of Fuess, of Berlin, are generally used. In them the proportion between the cistern and the tube is allowed for on the scale, so that but one adjustment is necessary. The cost is 100 marks. Each instrument is compared, either directly before being sent out, or afterwards by the inspector's travelling barometer, with the Wild-Fuess standard. The other instruments are likewise tested at the Institute before being distributed to the observers. The psychrometer costs 30 marks, and, together with the maximum and minimum thermometers, are by Fuess. The maximum has a constricted tube according to Negretti and Zambra's principle; the minimum, on Rutherford's system, a forked bulb, and both can be

transported without injury. The thermometers were formerly exposed on an iron frame projecting from the north side of the house, and unprotected from rain. The new stations have a zinc thermometer screen, painted white, with segmental revolving sides and roof, after the Seewarte model. It is made larger, however, so that it can contain a fan, turned by clock work, which is set in motion 20 minutes before an observation, and a Hottinger hair hygrometer. The screen is extended from a wall and can be swung in front of a window when an observation is taken.

The new rain gauges by Dr. Hellman have a receiving surface of $\frac{1}{50}$ sq. m., with a turned brass ring, and are 45 c. m. deep. At the bottom is a can in which the water is collected and then let into a measuring glass, graduated to tenths of mm. The receiver is hung on a post about 1 m. above the ground, and each station has two such receivers. For snowy regions the receiver sets into a larger vessel, so that the snow is prevented from blowing out. A conical cover during rain prevents evaporation. The stations of the Society for Agricultural Meteorology in Central Germany generally use the Assmann combination gauge with a receiving surface of $\frac{1}{20}$ sq. m. 1 m. above the ground. Two receivers are placed one above the other, so that when one is taken away for melting the snow, the lower one remains, the metal ring being transferred to the exposed receiver. Some of the stations are provided with Wild's pressure plate and wind vane, which consists of a rectangular plate hung by its upper edge and kept normal to the wind by the vane. The arc, over which the plate moves, is divided in eight parts, corresponding to velocities of meters per second. There are but few anemometers in use, one of these being in Berlin. A few stations have earth thermometers on Magnus' system and for the surface temperatures. All stations are regularly inspected each year by Drs. Hellmann, Assmann, Sprung, and Kremser.

Publications.—The observations have been published annually since 1849 with the *Prussian Statistics.* The volume for 1885, which appears independently, contains the tri-daily observations at eight stations, including observations on the Schneekoppe

(1,603 m.) and at the corresponding valley station. The monthly and annual summaries of these and the other stations are printed according to the international form. Among special data are to be noted the direction of motion and the time of appearance of the cirrus clouds at Lichtenwalde, in Silesia, for each day of the year, bi-hourly observations of wind direction (monthly sums) at Schwerin, in Mecklenburg, and hourly wind velocities at Berlin. Since 1883 the Institute has published, through the Statistical Bureau, a monthly summary of the weather, derived from the observations at 30 stations having long records from which the deviations from the normal values can be obtained.

THE BERLIN WEATHER BUREAU.

As previously stated, no weather forecasts are issued by the Prussian Meteorological Institute, but a private bureau for the purpose exists in Berlin. It is located in the Agricultural High School, whose physical department makes meteorological observations and possesses a registering barometer and anemometer. The head of the department is Dr. Börnstein, and the private bureau for weather forecasts is directed by Drs. Less and Lipkowitz. These forecasts, which are made for Berlin and neighborhood, are based mainly on the 8 A. M. reports from 48 foreign and domestic stations, received soon after noon from the Deutsche Seewarte. These reports are immediately deciphered and entered on a chart, the isobars from 5 to 5 m. m. drawn, and the clouds and wind indicated by symbols. From these data, and from the local observations, predictions of wind force, cloudiness, precipitation and temperature are issued about 3 P. M. for the 24 hours from midnight. The isobars and symbols of the charts are engraved upon stereotyped maps, and printed the same evening in one Berlin newspaper and the next morning in three others, together with the predictions, which are published alone by other journals. These predictions, as verified at Berlin by rules which do not vary greatly from those of the Seewarte, gave a percentage of success in 1885, for the four elements, of 83. For the single elements the percentages were as

follows: Wind force, 84.; cloudiness, 82.; precipitation, 81.; temperature, 83.

THE OBSERVATORY OF THE COLOGNE GAZETTE.

For the past eight years local weather predictions have been made by Dr. Klein, the astronomical and meteorological editor of the Cologne *Gazette*. Dr. Klein is a strong advocate of local *vs.* general weather predictions, and has stated that predictions of the five elements—wind direction and force, temperature, cloudiness, and precipitation—made 36 hours in advance and based purely on local eye and instrumental observations, give a higher per cent. of success than do the general predictions of the Seewarte for N. W. Germany, tested at Cologne. But the predictions published in the *Gazette* are based largely on the following telegraphic reports received between 12:30 and 1 P. M.: (1) The so-called subscription despatch of the Seewarte, giving the barometer, thermometer, wind and clouds, at 28 German and foreign stations for 8 A. M.; (2) the 8 A. M. report of 8 other foreign stations received from Hamburg; (3) direct reports of the 8 A. M. and 1 P. M. observations at Münster and Saargemünd, the condition of the weather of Hamburg at noon, and the weather in London the same morning. The telegraphic material is charted upon a blackboard map, the isobars drawn and the wind direction and state of sky indicated by disks. A general synopsis of the weather is received from the Seewarte and printed with the tabular reports. It does not arrive in season to be used in making the predictions, which must be ready by 1:30 P. M., as the *Gazette* appears at 3:30. The predictions apply for the 24 hours from midnight, and are recorded in numbers according to the Seewarte code. The weather experienced is expressed in the same manner, so that the verification of the predictions by — (failed), + (succeeded) or ± (partly correct) is easy. The percentage of success during 1882 for the several elements was for weather, 82; wind, 81; temperature, 85; and for these three elements together, 83.

This observatory possesses the ordinary meteorological instruments, and observations are made at 8 A. M., 1 and 7 P. M., accord-

ing to the scheme of the Prussian Institute. A special study of cirrus clouds has been commenced by Dr. Klein from the observations at a large number of stations, with a view of utilizing them as warnings of approaching storms. In summer the rain-band spectroscope is employed to furnish indications of rain. Among other apparatus is an ingenious seismograph and a transit instrument, the determination of mean time being an important work of the observatory.

THE OBSERVATORY OF THE MAGDEBURG GAZETTE.

This observatory was intended to be not only the head-quarters of the weather predictions for the province of Saxony and its neighborhood, but in connection with this, to benefit meteorology, especially as related to agriculture, by the discussion of data not usually obtained. For this reason observations of radiation and insolation, duration of sunshine and temperature at the height of growing grain were here begun. For the same purpose a Society for Agricultural Meteorology, with the observatory as its central station, was founded by Dr. Assmann, the superintendent. Dr. Assmann resigned his position in 1886, and was succeeded by his former assistant, Grützmacher, who has, in general, carried out his predecessor's plans. The cost of maintaining this observatory is about 12,000 marks annually.

The Observatory and its Instrumental Outfit.—The observatory was built in 1880 by Messrs. Faber, the proprietors of the Magdeburg *Gazette*. It consists of an octagonal brick tower, 34 m. high and 4 m. in diameter at the base, adjoining the Faber printing establishment, whose situation on the extreme west of the city is favorable to meteorological observations, while the tower dominates all the surrounding buildings. In the basement are these instruments: The normal Fuess siphon barometer, reading to .05 mm.; a siphon Greiner barometer, altered by Fuess, serving also as normal barometer; several closed cistern barometers, and a Sprung barograph multiplying four times. A normal clock closes the circuits for the barograph and ombro-anemograph on the roof. The superintendent's room is in the adjoining building, which contains the observa-

tory library connected by an elevator with the upper stories of the tower. Thus books and papers may be quickly transferred from one story to another, with which speaking-tubes facilitate communication. Entrance to the tower is over the flat roof of the main building. A gas furnace in the corresponding floor of the tower heats the whole tower, but especially the upper portion. From an east window is built a thermometer screen of the Seewarte model, protected on the east and south by double louvres. The wet and dry bulb and maximum and minimum thermometers here are 17 m. above the ground. In the next story is a work-shop, with a thermometer comparator; the room above serves as a store-room for papers, etc.; still higher is the bureau of the assistant. Surmounting the eighth story is a glass cupola, 3 m. high and 3.5 m. in diameter, with a gallery outside. It contains the following instruments: The anemograph, in the middle, is actuated by a set of Robinson's cups and a vane, the latter placed under the cups; the spindles are concentric, and so connected that for each 100 revolutions of the cups a type upon a prolongation of the vane axis is dropped upon a band of paper which is reeled out at a uniform rate by a clock. The direction and velocity of the wind are thus registered together upon the band, the direction by an arrow and the time each half hour by a point. To record the direction when the wind is light, another apparatus is used. A pencil connected with the vane spindle travels round a cylinder which is dropped by a ratchet a little each time a contact is made by the clock. The registering rain-gauge is placed on the cupola, 33 m. above the ground. It has a receiving surface of 0.05 sq. m., and is surrounded by a Nipher screen of wire, from which satisfactory results have not been obtained. The rain passes from the receiver through a pipe upon a tilting spoon which is depressed by the first few drops of rain, and thereby closes an electric current which registers the time during which rain falls upon the tape of the anemograph. The amount of rain is measured in a graduate, and is considerably less than that caught on the ground; snow is melted by a gas flame underneath the receiver. On the gallery of the tower, 32 m. above the ground, is a Wild

thermometer hut, protected on the south by triple, on the east by double louvres, and open to the north and at the bottom. It contains a metallic screen with similar thermometers to those below. On the south side of the gallery is a Fuess vacuum solar thermometer and a Campbell-Stokes sunshine recorder. The rain-band spectroscope is frequently and regularly used to determine the humidity of the whole atmosphere.

In a neighboring garden are exposed the following instruments: 3 earth thermometers of Lamont's construction, in wooden cases, at depths of 1, 3 and 5 m. The normal thermometers for air temperatures are placed under a Wild hut, in a metallic (Seewarte) screen, with their bulbs 2 m. above the ground. The minimum thermometer has a forked bulb and the maximum an air bubble index. The screen also contains a Koppe hair hygrometer. There are also in the garden 3 earth thermometers at depths of 0.15 m., 0.05 m., and flush with the earth's surface; maxima and minima with their bulbs covered with earth, on bare ground and on grass and 0.05 m. above it, and formerly 10 were over grass at successive vertical intervals of 0.1 m. For the last series are now substituted 5 maxima and minima, lying on the ground, one pair horizontal, the others inclined and directed to the cardinal points of the compass. A Marié-Davy actinometer is 1.5 m. above the ground. Two rain-gauges 1 m. above the ground have receiving surfaces of 0.05 sq. m. One is by Fuess, the other is the double gauge of Assmann. A Wild evaporimeter, 1.2 m. above the ground, is in a louvre screen. The pan with an exposed surface of 250 sq. cm. rests on a balance in which 25 gr. correspond to 1 mm. evaporation. The height of the ground water is indicated by a float in an iron pipe extending 7 m. into the soil.

The Observations and their Publication.—In conformity with the practice of the Seewarte, the observations are made at 8 A. M., 2 and 8 P. M., besides the synchronous Washington one at 12:45 P. M. The barometer, at a height of 54 m., is reduced to 0° C.; the absolute and relative humidity are calculated by Jelinek's tables; wind force and cloudiness are estimated on a 10 part scale. The rain-fall is measured three times a day in the gar-

den, and the totals at 8 A. M. entered to the preceding day. The international symbols and other abbreviations are employed. The mean daily temperature from May to September is calculated from the formula

$$\frac{\frac{1}{2}(8\text{ A. M.} + 8\text{ P. M.}) + \frac{1}{2}(\text{max.} + \text{min.})}{2}$$

and from October to April by the formula

$$\frac{\frac{1}{2}(8\text{ A. M.} + 8\text{ P. M.}) + \frac{1}{3}(8\text{ A. M.} + 2\text{ P. M.} + 8\text{ P. M.})}{2}$$

The wind directions are reduced from 16 points to 8 points. Occasional simultaneous readings of the psychrometer at three heights were made for one year, and in the following years tridaily observations were carried out. The Lamont earth thermometers are read about noon, the earth thermometers and the Marié-Davy actinometer three times daily, and observations of maximum insolation, extremes of earth surface temperature, evaporation, and height of ground water, are made daily.

These results have been published *in extenso*, according to the international scheme, in the *Jahrbuch der Meteor. Beobachtungen der Wetterwarte der Magdeburgischen Zeitung*, which with 1885 reached its fourth volume. The first year contained also the hourly values of pressure, wind direction and velocity, and duration of sunshine. The last volumes, however, give the actual traces of the barograph and sunshine recorder instead of the hourly values, but the hourly means of pressure for the month and year are tabulated.

Weather Predictions.—About 11:30 A. M. a despatch is received from the Seewarte, giving the barometer, wind direction and force, cloudiness, rain and temperature at 25 stations in Germany, the Netherlands and France. These data are immediately charted, the isobars and isotherms drawn, and in connection with the local observations, especially those of the barometer, anemometer, rain-band spectroscope and cirrus clouds, a local prediction is made at once for the next day, which appears in the evening edition of the *Gazette*, and is telegraphed in a five-place cipher word to a number of newspapers, societies and individuals.

At 2 P. M. the subscription despatch arrives from the Seewarte. From this and the auxiliary and isobar telegrams, the weather chart for that morning is drawn, and printed in the next day's paper by means of an English process. This chart gives the isobars for each 5 mm., the weather and wind by symbols, and the temperatures in figures. A general synopsis of the weather and the tri-daily observations at Magdeburg follow. The morning observation, and that of the preceding evening, are sent to the Seewarte together, and in winter separately. On Saturday and on the day before a holiday a despatch is received in the evening from the Seewarte, giving in words the European weather situation. With the morning data this serves as a basis for forecasts covering two days.

The success of the predictions estimated by the Seewarte method gave in 1882 the following percentages for the different elements: Weather, 83; wind, 79; temperature, 77; precipitation, 76; average, 79.

INSTRUMENTS FOR MAKING OBSERVATIONS OF THE AMOUNT AND DIRECTION OF THE WIND.

By Frank Waldo.

From the earliest times the wind has been the great labor-saving help to mankind, and until the present century was the only motive force (except an occasional water-fall) that could take the place of the muscular exertion of mankind or his trained "beasts of burden." Notwithstanding the great usefulness of the wind, and the fact that general observations have been made on it for hundreds of years, it has been only within the present century that system has been introduced in the making and recording these observations, so that the results obtained for different observers are comparable.

I. *Amount of Wind.*

We will take up for consideration, first, the amount of wind.

If a person unused to noticing carefully the changing velocities of the wind is asked to make an estimate of the number of

miles per hour a wind is blowing, he would have no idea as to what answer to give. Or if he is asked to give the force with which the wind would blow against a square foot of surface (exposed vertically) he would be equally at a loss for an answer. If, however, he is asked whether the wind is blowing one-half, one-third, or one-quarter as hard as the most violent storms he has encountered, he could probably, after a little consideration, give an approximately correct answer. If, now, it is assumed that a calm is represented by 0, and the most violent storm is represented by 10, a little practice will enable an observer to give the proper number between 0 and 10 to the various winds from calm to the strongest gale. This is the scale adopted by the "International Congress of Meteorologists," in order that the estimated wind velocities of different countries may be comparable with each other.

On the ocean, however, the Beaufort scale (from 0 to 12) is still in use, and will probably continue to be used for a long time to come, as it has become so generally adopted since its introduction by Admiral Beaufort in 1805. Another popular scale of estimation on land is from 0 to 6, which can be easily compared with the Beaufort scale, by multiplying by 2. Silll another, and perhaps more natural division, is the Mannheim scale, 0–4. Many observers prefer, however, to use the more readily understood expressions, calm, gentle, fresh, strong, gale, hurricane, to indicate the various grades of wind.

An observer soon acquires considerable skill in making estimations according to any particular scale. Seamen, naturally paying the most attention, become very accurate observers, and even when they are on board a ship in motion they can judge pretty closely the true velocity of the wind,—when the observers are stationary, the accuracy of an "estimation" is perhaps equal to that observed by instrumental means.

Various forms of instruments have been devised for measuring the wind velocity and force. The one at present almost universally adopted is the Robinson velocity anemometer, so-called from its advocate, who published a theoretical and practical investigation of its method of action in 1850.

The instrument consists of four hemispherical cups of thin metal, attached to the extremities of two light metal rods crossing each other at right angles, so that all of the four arms formed by the rods are of the same length. The cups are attached to the arms (as the rods are called) in such a manner that they all face the same way, that is, either to the right or to the left. The arms are placed in a horizontal position, and are clamped to a vertical spindle at their intersection. This spindle passes downwards through a hollow stand encircling it, which supports it, but does not prevent its turning as freely as possible, except that the unavoidable friction will offer a slight resistance. The lower end of the spindle rests in a bearing (where also the friction has been reduced to a minimum), and carries, just above the end, an endless screw encircling it. This endless screw has a small toothed wheel geared into it so that the wheel is turned by revolving the endless screw. This wheel is geared into a series of wheels, each of which may have an indicator and a dial to show the number of revolutions.

If, now, the instrument is exposed to an air current, the unequal pressure of the air against the exposed convex and concave surfaces of the cups will cause the cups, and consequently the spindle, to rotate with the vertical spindle as an axis. This rotation is communicated to the train of wheels, and the number of revolutions of the anemometer cups around the vertical axis can be read off from the dials of the wheels, these being so arranged that a certain number of revolutions of the spindle cause one revolution of the first wheel, and a certain number of revolutions of this wheel cause one revolution of the second wheel, and so on. By means of this apparatus the number of revolutions of the anemometer cups is obtained; and the distance passed over by the middle point of one of the hemispherical cups is, of course, $2 \times 3.1416 \times R$, where R is the radius of the circle described by this middle point. But this is not the true velocity of the wind. Mr. Robinson found by experiment, however, that if the velocity of the cups is multiplied by 3, it will give approximately the velocity of the wind. And this factor 3 is used by all nations in the reduction of the anemometer obser-

vations. In order to save the labor of making this reduction each time, the wheels and dials of anemometers are so made that the miles and fractions, or kilometers and fractions, can be read off directly, the factor 3 being taken into account.

The invention of the cup anemometer is attributed to Edgeworth (by Jelinek), but in the Royal Ethnographical Museum at Berlin there is an apparatus very similar to the cup anemometer, only it is made of wood and the cups are oval; this came from Thibet, and illustrates a form of wind-mill, the small copy being used as a wind-mill god, and in connection with this Dr. Grünwedel (of the museum) remarks that in Pallas' "Mongolische Völker," 1770, there is a diagram of a similar apparatus. So that, although Edgeworth may have used it first as a scientific instrument, and probably reinvented it, the idea is a very old one.

Robinson's theory of the instrument, published in 1850, was not very satisfactory, although the results were approximately correct. The constants to be used in his formulæ he determined by experiments with a large anemometer, and as a result he found that the velocity of the center of the cups must be multiplied by 3.00 in order to get the wind velocity. Robinson found that a small anemometer tested also on a rotating arm (Combe's apparatus) gave nearly the same results, and meteorologists generally accepted this value.

Other experiments of Cavallero in Turin, and Stowe in England (1872), showed, however, that this result was only approximate; the latter's observations making it clear that the constant of multiplication (adopted as 3) is not the same for anemometers of different dimensions, but varies with the relation between the radius of the circle through which the cups move and the radius of the cups themselves.

Professor Wild, of St. Petersburg, caused a Combe's rotation apparatus to be mounted in the large instrument room of the "Central Physical Observatory," and Dohrandt made many experiments on instruments of various sizes (1873).

It is impossible to give a summary of Thiesen's (1875) and Robinson's (1850) (1876) theoretical deductions in a popular

paper like this, because it would be necessary to introduce complex mathematical formulæ. Although the theory of the instrument has been given by these expert mathematicians in the general terms of hydrodynamical analysis, yet they both consider that the subject is one that can be best treated by experiment. And while the theory may serve to outline the general action of the instrument, still in actual practice, it is better to investigate each separate instrument as must be done in the case of thermometers.

There are several methods of testing anemometers. The instrument can be mounted on a locomotive, and the number of revolutions of the anemometer cups, and the time noted as each mile post is passed. A straight track must be chosen, and observations must be instituted at the stations along the line to determine the velocity and direction of the wind blowing at the time the observations are made, so that this may be allowed for in the observations made on the locomotive.

Another way is to mount an anemometer in a free exposure, and allow toy balloons to be set free to windward, so that they will pass very near to the anemometer; the balloon being so weighted that it will rise very slowly, its passage (transit) across wires fixed one or two hundred feet apart can be noted. If the time is noted by means of an electric chronograph, the error of an observation ought not exceed one-tenth of a second. The velocity of the wind, as shown by the anemometer, being noted at the time the observation of the balloon is made, the two velocities can be compared. If a large number of such observations could be made for various wind velocities, it would probably furnish a good standard.

The method usually adopted of mounting several anemometers side by side, with the same exposures, is very well for determining the results of the anemometers *inter se*, but it does not determine the absolute error of the instruments. However, if the instrument adopted as a standard has been tested for absolute velocities, the principal objection to this method of testing anemometers is removed, although it requires a great deal of time, as the comparison must be made at high as well as low veloci-

ties, and the observer often has to wait days or even weeks to get these contsts.

Still another method is the use of a Combes' rotation apparatus, and as this can be used at any time and for any velocity, up to its limit, at pleasure, it has many advantages of convenience over the other methods.

The Combe's rotation apparatus (according to Thiesen, used by Smeaton and Zeiher before Combes) has been mentioned several times, and a detailed description of it will be given, as nothing of the kind has as yet been constructed in this country.

The apparatus consists of a horizontal arm of at least ten feet in length; this arm has a horizontal motion around a vertical axis at one end of it. The free end carries another vertical arm to which is attached the vertical spindle of an anemometer, the cups being horizontal. The long horizontal arm is now made to rotate about the vertical axis at the one end by causing this vertical axis to rotate, which can be done by a small engine of one or two horse-power. (Man-power has sometimes been used). The anemometer will sweep through a circle (horizontally) of which the revolving axis is the center and the long horizontal arm the radius. The motion of the anemometer causes a resistance from the air, which acts on the anemometer in nearly the same way as if the anemometer were at rest, and the wind was blowing with the same lineal velocity that the anemometer has in its revolution. Of course the space passed over by the anemometer can be readily computed when we know the length of the horizontal arm; and if the time is noted in which a certain number of revolutions is performed, and a reading of the anemometer dial is made at the beginning and end of this time, we can find out how many feet of motion of the anemometer cups around the spindle correspond to the number of feet passed over in a second by the whole anemometer at the end of the revolving arm. Knowing the *actual* velocity of the counter-wind caused by the rotation of the arm, the readings of the dial of the anemometer cups can be reduced to actual measure. There have been several such apparatus constructed: by Robinson in Ireland; Stowe and

Whipple in England; Hageman; Rechnagle, Neumayer, in Germany; Wild in Russia; ——— in Italy, etc., but the most complete one is that of the Deutsche Seewarte, at Hamburg, Germany, constructed by Neumayer.

This last mentioned apparatus is located in the middle of an inner court, which is closed at the top by glass roofing, and is surrounded by corridors opening into the court.

The long horizontal arm is not more than three feet from the smooth polished floor, but the anemometer is perhaps seven feet above the floor, and three times that distance from the ceiling.

The vertical axis of the revolving arm passes downward to a trap just beneath the floor, and in this trap the rotatory motion is communicated by a horizontal axis by means of a conical gearing, and this long horizontal axis is rotated by means of a gas motor in the basement. At one side of the court there is a frame supporting a small anemometer which can be placed just above the path of the center of the anemometer to be tested. This small anemometer is for measuring the velocity of the weak current of air produced by the motion of the anemometer, and which has a motion *with* the anemometer. (Germ. *Mit-wind*).

In one corner of the court there is a little balcony where the observer may place himself when the apparatus is in motion. Here there is a crank handle that has communication with two conical cylinders in the basement, near the engine, around which the driving belting passes. By means of the crank this belting is caused to slide along the cones so that the velocity of the driving arm, and consequently of the rotation apparatus and the anemometer, can be varied by the operator in the balcony.

In this balcony is mounted also a chronograph on which is automatically registered electrically the seconds, the number of revolutions of the long rotation arm, and the number of revolutions of the anemometer cups.

In the case of the latter the contact apparatus is arranged as follows: the anemometer dial wheel is made one pole of a bat-

tery, and a metallic point which is the other pole of the battery comes in contact with the wheel, at the completion of a chosen number of revolutions of the anemometer cups, and thus closes the circuit and causes a registration in the chronograph; the two wires from the anemometer pass down the vertical support and along the rotation arm and down the rotating axis, and terminate each in a metallic band which is always in contact with a metallic ball which is free to move around on a fixed metallic rim encircling (but not touching) the axis of rotation; a wire passes from each of these circular plates to a pole of the battery, the chronograph being included in one of them.

The rotation arm is also provided with a metallic arrangement which closes another circuit for an instant at each revolution, and this record, together with that of the anemometer cups, and the beats of a seconds pendulum, being registered side by side on the chronograph, a comparison of the registrations can be readily made.

The actual manipulation of this whole apparatus requires much care, and in taking for an example an actual case of testing an anemometer I shall use one from a recently published investigation at St. Petersburg, by Stelling. Mention has been made of a current of air caused by the motion of the anemometer, and it has been found (at St. Petersburg) that a small Woltmann's anemometer placed near the path of the large anemometer shows a current *with* the large anemometer amounting in velocity to about five per cent. of the velocity of the latter, and this rule holds good up to seventy kilometers per hour. So that the actual reading of the anemometer must be changed by this per cent. in order to get the true reading. Dohrandt and Stelling place this small anemometer at the side of the large anemometer and in the same horizontal plane, but Neumayer provides for its being placed just over the point where the center of the anemometer cups passes. This seems to give a steadier rotation to the small anemometer, the velocity of which is greatly increased by the large anemometer passing near it, this velocity growing gradually less until the revolving arm again sweeps by it.

But first of all the Woltmann's winged anemometer must be tested, and an actual case given by Stelling is as follows:

v	C_1	C_2	C	v'	$v-v'$
1.87	29.8	30.2	30.0	1.85	+0.02
3.75	63.4	64.4	63.9	3.78	−0.03
6.24	106.2	108.0	107.1	6.23	+0.01

Here v is the velocity of the anemometer (on the rotation apparatus) in kilometers per hour. C_1 is the number of contacts made by the electrical apparatus in connection with the wings of the anemometer in the course of an hour, when the rotation arm is made to sweep around in the direction N.E. S.W.; C_2 is the number of contacts in an hour when the direction of rotation is N.W. S.E., and C is the mean of the results from the two directions. If now we form three equations

$$1.87 = x + y\ 30.0$$
$$3.75 = x + y\ 63.9$$
$$6.24 = x + y\ 107.1$$

and solve them for x and y by the method of least squares, we find

$$x = 0.15 \text{ and } y = 0.05673.$$

Then by writing the equation

$$v' = 0.15 + 0.05673\ C$$

we have a single expression that will give us the amount of wind v' in kilometers per hour corresponding to the number of contacts C occurring during that hour. As the induced air current is never more than about five per cent. of the velocity of the anemometer to be tested, it was not necessary for the test to be made for greater velocities than five kilometers per hour.

An anemometer, "Shadewell No. II," belonging to the Prussian Meteorological Bureau, was investigated by Stelling, and he found the following values:

v'	C_1	C_2	v''	$v-v''$
10	25.3	18.7	9.87	+.13
20	54.4	39.8	20.14	−.14
30	84.7	61.9	30.25	−.25
40	116.0	83.6	39.86	+.14
50	150.2	107.5	49.65	+.35
60	189.4	137.2	60.33	−.33
70	228.4	167.2	69.93	+.07

In this case the formula

$$v'' = 0.41 + 0.4399\ C - 0.000447\ C^2$$

was obtained in a manner similar to the equation for v' previously found; only in this case a third constant, z, was introduced as a coefficient of C^2 in the original equations. Dohrandt found that the coefficients x and y were sufficient for velocities under 50 kilometers per hour, but Stelling shows that for velocities of 60 or 70 kilometers per hour the use of the third constant, z, greatly reduces the residuals $v—v''$. (This is an excellent example of the influence of the method of reduction of observations on the result deduced from the *same observation.*)

Now, although it would be much the best way to test each anemometer for eight velocities ranging from 0 to 70 kilom. per hour and deduce a formula similar to the one for v'' just given, yet as so few meteorological services are provided with a testing apparatus wherewith to test each instrument, and as there is no uniformity as regards the dimensions of the various parts of the anemometers constructed by different makers, various attempts have been made to deduce by means of a formula the results of anemometers of different makes to a uniform standard, so that these results can be intercomparable. Thiesen found, from a theroretical investigation, an expression for the relation of the different parts of an anemometer, but its complexity and the impossibility of determining the values of the constants without further experiment prevents its use in actual practice.

Dohrandt tested ten anemometers of various dimensions on the Combe's apparatus at St. Petersburg, and after considerable experimenting hit upon the following formula as fitting all of the anemometers with as much agreement as could be expected:

$$B = 3.0133 - 53.7367 \frac{R^2}{r} + 1033.81 \frac{R^4}{r^4}.$$

Here B is the desired co-efficient of the second term of a linear equation, R the radius of the anemometer cup, and r the distance from the center of the anemometer spindle to the center of the anemometer cup.

The complete linear equation for the reduction of anemometer readings to wind velocities is $w = K + Ba$ (as given by Köppen), where w is the wind velocity,

K is the friction constant with an adopted mean value of 1.0 m. p. s.,

a the velocity of the center of an anemometer cup,

B the constant computed by the formula given above for the values of R and r belonging to the anemometer in question.

The residuals of the different anemometer results as deduced by this common formula are for the nine anemometers of different dimensions: 3.2%, 4.3%, 2.3%, 0.4%, 0.8%, 0.1%, 1.2%, 6.2%, 1.1%, being an average deviation of only about 2%,* which is a small amount when we consider that differences of 30% may occur in the case of the Robinson factor three, which is now so universally adopted.

II. While the velocity of the wind is what we measure by means of the Robinson anemometer, yet the force with which it blows against any object is really what we want to know for practical purposes. This may be determined in several ways. A common form of apparatus is to expose a plate (say a foot square), vertically, in such a manner that the wind will blow square against it; this is accomplished by having the plate mounted with its broad surface at right angles to the longitudinal direction of a large wind-vane with which the frame supporting the plate must be in rigid connection. This holds the surface of the plate at right angles to wind, and thus causes the horizontal component of the wind-force to exert the maximum pressure on the plate. At the back of the plate there is a stout spring which the plate is free to compress, and we measure the force with which the wind presses on the plate by the amount of compression of the spring. Ferrel gives the following theoretical formula for the relation between the velocity and pressure of wind.

$$p = \frac{0.002698\, v^2}{1 + .004t} \frac{P}{P_0}$$

where

p is the pressure in pounds per square foot,
v is the velocity in miles per hour,
$P_0 = 760$ mm,
P = actual barometer reading,
t = temperature centigrade;

* We think that the rule adopted by the Signal Service allows a difference of 4 per cent. in anemometers of the same dimensions and construction.

and for sea-level and $t = o$ he gives the following theoretical relation between wind pressure and velocity:

Veloc.	Force.	Veloc.	Force.
Miles p. h.	Pounds.	Miles p. h.	Pounds.
5	0.07	100	27
10	0.27	150	61
20	1.08	200	108
40	4.32	250	169
70	13.23	300	243

Experiments on small plates a few inches square have shown that the Theoretical p : True p :: 1 : 1.3, but this relation is somewhat uncertain.

Another form of pressure instrument is the "Wind-Force Tablet," the best form of which is that used by Wild. This instrument, as made by Fuess, consists of a metal plate suspended vertically by means of a horizontal rod around which it is free to turn. This plate is kept with its surface facing the wind by means of the small wind-vane beneath it. The wind blowing against the plate causes it to turn on its horizontal axis, and the angle through which it turns in the vertical varies with the force of the wind.

In this operation there are two forces at work. Gravity draws the free end of the plate towards the vertical position, and the amount of this force is termed the moment of the gravity. The second force is that of the wind pressing the plate so that the free end is pushed from the vertical, and the amount of this pressure is called the moment of wind pressure. Dohrandt and Thiesen tested small plates of various dimensions on the Combe Rotation Apparatus at St. Petersburg, and Thiesen has investigated the action of the plate from theoretical consideration.

Thiesen finally deduces the following formula for the reduction of the observed angular displacement of the free end of the plate from the vertical, to meters per second of wind velocity:

$$W = A \frac{1}{\sqrt{e}} \sqrt{\tan \Phi} \frac{\sqrt{1 + \cos \Phi}}{\sqrt{\left\{1 - \frac{a}{c} \frac{\sin \Phi}{1 + \cos \Phi} 0.31\right\}^2}}$$

$$A = \sqrt{\left\{\frac{G\,(c - S)\,1000}{a\,b\,c\,(7.07 + (a + b)\,0.0225)}\right\}}$$

where W is the wind velocity in meters causing the angular deviation of the plate by $\varphi°$ from the vertical, G the weight of the plate in grammes, a the length and b the breadth of the plate, o the distance of the center of the plate from the axis of rotation, $c—S$ the distance of the center of gravity from this axis expressed in centimeters, e the density of air referred to a normal density of 758^{mm} barometric pressure and a temperature of $15°$ C.

In case the correction for density and temperature of the air is to be applied, Theisen found the formula:

$$\frac{1}{\sqrt{e}} = 1 + 0.0018\,(t - 15°) - 0.00066\,(h - 758)$$

where t is the observed temperature and h is the observed barometric pressure. Thiesen ends his paper by the following remarks and table:

"The wind-force plates, furnished the Russian Meteorological Stations by the Central Physical Observatory of St. Petersburg, are on the average 15 × 30 centimeters and weigh 195 grammes *without the frame.*

"Accordingly a square centimeter of its *tin* weighs 0.433 grammes and $A = 7.31$."

For these plates the following table holds good:

"W =	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m	11m	12m	15m	20m
φ =	1.1°	4.1°	9.2°	15.7°	23.0°	31.0°	38.7°	45.7°	52.1°	58.0°	62.5°	66.4°	74°	80.5°

A change in the total weight of ± 1 gramme will give a change in the velocities of 0.25%."

The Wild wind-force plate and vane combined, is an inexpensive and satisfactory instrument for making wind observations at stated times, and its introduction into our State Weather Services would greatly increase the uniformity of the results from different sections of the country.

We need, however, further experiments, with the aim of making a more accurate comparison of the anemometer, wind plate with springs, and the Wild wind-force plate, with actual wind velocities, and it is to be hoped that the Signal Service will undertake such a work, as it is the acknowledged leader of meteorological work in America and its standards are in great measure adopted by our practical meteorologists.

The following suggestions show some of the desirable experiments:

1st. By means of a portable Combe's Rotation Apparatus compare standard instruments of the various forms at about sea-level (Washington), at Denver, Colorado, and at Pike's Peak. The apparatus could easily be mounted in some protected place, out of the action of the wind, at Washington and Denver, but considerable difficulty would be experienced at Pike's Peak, although a spot could probably be found below the summit and to leeward which could be protected from the wind by aid of canvas covering. Comparison of these standards when exposed to the natural winds should also be made at these altitudes.

2nd. Comparison of the various forms when mounted on the front of a locomotive.

3rd. Comparison of the different forms and various dimensions at observing stations where the range of wind velocities is greatest; for instance, at Mt. Washington or Cape Hatteras.

4th. The comparison between the readings of the instruments for measuring wind-force and velocity, and the velocity of a puff of smoke, or a toy balloon, as determined by its transit across wires placed one or two hundred feet apart; the times of transit being noted to within a small fraction of a second by means of a good clock or breakcircuit chronometer and a chronograph.

Another kind of wind measure is the pressure anemometer of Lind, in which a tube is bent in a U form with one of the ends turned at right angles to the main leg of the tube so that the mouth is vertically placed, *i. e.*, so placed that a horizontal air current blowing against it will enter the tube. This tube turns on a pivot, and is so combined with a wind vane that this latter will always keep the mouth of the tube turned towards the direction of the approach of the wind. If, now, a liquid (water, for instance) is poured into the tube, the pressure of the wind on the surface in one leg will depress this surface and cause a corresponding rise in the water in the other leg.

The amount of this difference of levels in the two legs will be

proportional to the pressure caused by the wind acting on the one surface to the full effect of its force.

Still another form is the Hagemann Aspiration Anemometer. According to Wild, this instrument (as made by Nyrop, of Copenhagen,) consists of a vertical tube, (to be set up on the roof or wherever the exposure seems best) the upper end of the tube having a conical mouth-piece with an aperture of 3^{mm}; the lower end of the tube being connected with a lead tube which leads to the apparatus for measuring the pressure. This last consists of a cylindrical vessel (with a scale) partly filled with water, and which envelops a receiver which is closed at the top but open below. This last is hung onto the axis of the index pointer by means of a thread, its weight being counterbalanced by means of a side spring, which at the same time endeavors to turn the axis towards the opposite side by means of a thread twined around it. The narrow lead tube leading from the roof opens into the part of the receiver (or bell) occupied by the air.

Now, when the wind blows across the conical mouth-piece on the roof, it causes a diminution of the air pressure in the lead tube and also in the receiver, and this allows the latter to sink in the water until it is held in equilibrium by the spring. This motion is communicated to the index pointer and the amount read off on the scale. The scale divisions are purely arbitrary and can denote either velocity or force, but each instrument must be compared with a standard anemometer or pressure plate before it can be used for making observations, and this comparison must take place after the Hagemann's anemometer has been mounted in the place where it is to be used.

This instrument could easily be made self-registering, and its applicability at all seasons of the year would seem to recommend its use at elevated mountain stations where the frost work interferes with the working of the Robinson anemometer.

Abbe has suggested a combination of the Lind-Hagemann instruments, in which he uses aneroid barometers to show the differences in pressure.

II. *Wind Direction.*

The instrument used for denoting the direction of the wind, is called the Wind Vane. This usually consists of an horizontal arrow revolving on a vertical axis, and so placed that the arrow head always points toward the direction of approach of the wind. Instead of one tail to the arrow, there is frequently put two, and placed at such an angle as will give the greatest steadiness to the vane, and at the same time render it sensitive to the changes in the wind's direction. The amount of this divergence of the two tails is frequently put at 22°, but authorities differ, not only as to what angle is the best, but also whether two tails or one is most desirable. This question can be settled best by careful experiments.

Another form is that used in the Beckley and similar anemographs, in which there is the arrow head, but in place of the tail two small wheel-shaped fans are placed, one on each side of the longitudual axis of the arrow. These wheels being of similar size and construction, keep the arrow head pointed in the direction of approach of the wind. The blades of the fan are inclined 30° to the plane of the whole wheel.

The wind vane is not always reliable, as is shown by a single incident that came under the writer's observation, in which two vanes of similar construction and mounted side by side performed revolutions in opposite directions during a gust of wind, this being probably caused by the greater friction (due to rust, perhaps) on one than on the other, so that they were pointing in slightly different directions when the gust came. As the question of direction of rotation of the wind is a very important one in many theoretical investigations, it seems that the indications of the wind vane may be erroneous, and not too much weight must be placed on their observed sudden motions.

III. *Self-Registering Instruments.*

There are numerous forms of self-registering apparatus for wind velocity and direction.

According to Westphal's researches, the attempts at construc-

ting apparatus for measuring and *recording* wind force and wind direction extend back to the year 1667, and the names of Hook, Pickering, Christian Wolf, Lentmann and Lenpold are given as being early experimenters.

Count d'Ons-en-Bray, in the year 1734, constructed a registering apparatus for wind direction very similar to the form devised later by Beckley; the wind velocity being recorded by means of a hammer raised by means of a small wind wheel and allowed to fall against a recording paper having a uniform motion, at every 400 revolutions of the wheel.

The Robinson anemometer register, in use in the principal European observatories, is the Beckley form, in which a long vertical rod is geared into the anemometer train work of wheels by means of an endless screw. At the lower end of this rod is a gearing by which a small horizontal cylinder is made to revolve (once for every 100 kilometers of wind in the Fuess Instrument). A spiral knife-blade-shaped strip of metal encircles the cylinder once in its whole length, and the edge of this metal blade touches a chronograph cylinder beneath it at one point only at a time; but during a complete revolution of the small cylinder, each point of the edge of the blade comes in contact with the chronograph at successive points from left to right. The chronograph sheet being of metallic paper, the contacts of the metal blade are recorded.

A similar arrangement records the wind direction, the small cylinder and its spiral metal strip making a complete revolution for each revolution of the wind vane, and a particular point of the strip always coming in contact with the chronograph sheet for the same position of the wind vane.

A very common form of anemometer register is the electrical, in which a platinum contact is inserted in the wheel work, showing the number of revolutions, in such a manner that for every kilometer or mile of wind, a circuit will be closed and cause a registration to be made on a chronograph. There is less friction with this method than with others. The wind direction can be registered by means of an electro-magnet and pencil for each direction; the circuit being closed automatically by the vane

entering the sector, of the circle of revolution, of which the direction is the middle point.

There are many more common methods of recording the wind direction. The simplest of these is to prolong the spindle rotating with the wind vane, to a room below, and let this spindle terminate in a conical bearing so that the friction will be small. Near the lower end of the spindle mount a cylinder encircling it and rotating with it. On this cylinder will be placed the recording sheet. Against this sheet there presses a recording pencil which has a slow motion in a vertical direction only, and which is regulated by clock-work. The cylinder rotating with the wind vane, and the pencil pressing against it continually, will cause the wind direction to be recorded for every instant of the time during which the pencil is moving in the vertical, which may be one day or several days, as has been allowed for in the construction. The motion of the pencil can be imparted by the driving weight of an ordinary clock.

WATER-SPOUTS OFF THE ATLANTIC COAST OF THE UNITED STATES.

Many of the readers of this JOURNAL will remember the discussion of Mr. H. B. Gibson on this subject in a previous volume. An important and interesting addition to the literature, is that of Mr. Everett Hayden, published as a supplement to the *Pilot Chart* of the North Atlantic Ocean for March, 1888. Mr. Hayden's paper follows:

"So many interesting reports have been received relative to water-spouts sighted by masters of vessels during January and February in the western portion of the North Atlantic, that advantage is taken of this opportunity to refer to them at greater length than can be done on the *Pilot Chart* itself, where, however, their positions are plotted graphically by means of an easily recognized symbol. Although the reports now at hand for these two months were received from incoming vessels only, yet they are very characteristic, and indicate fairly well the regions where these phenomena are of most frequent occurrence.

"Before quoting the reports themselves, it may be well briefly to refer to what is known regarding the character and formation of water-spouts, which are simply special cases of whirlwinds and tornadoes, as

these are special cases of cyclones, but on a much smaller scale. The general principles underlying all these phenomena may be stated as follows: A layer of warm moist air at the surface of the ocean happens to have above it a layer of cooler, drier air. This condition of things is one of unstable equilibrium, and sooner or later the warm, light air at the surface rises through the cooler and heavier air above. This process sometimes takes place gradually over large areas, but at other times it is more local, and there seems to be formed in the upper layer a break or opening through which the air of the lower layer begins to drain upwards, as through a funnel. Under favorable conditions—that is, when the differences of temperature and moisture and the supply of warm, moist air at the surface are great—this action becomes very intense, and this intensity is still further increased by the fact that as the air rises its moisture is condensed, the latent heat thus liberated adding to the energy of the rising column of air. Now, as this surface air rushes in and escapes upward through the opening thus formed in the upper layer, it takes up a rotary or whirling motion, the velocity of which increases toward the center or axis of the funnel, and a suction or partial vacuum is created, as indicated by the low reading of the barometer at the center of a cyclone or whirlwind. In the case of a great cyclone or hurricane, the direction of rotation is determined by the revolution of the earth about its axis, and the well-known law of storms is founded on the fact that this rotation is, in the northern hemisphere, invariably *against* and in the southern *with* the hands of a watch as you look at a watch laid down with the face up. In the case of tornadoes and water-spouts, this direction of rotation is not so uniform, although the same law holds good in most cases.

"When a whirlwind is thus formed over the ocean, water is often drawn up the center of the whirl some distance, owing to the suction created, and at the same time the moisture in the air is condensed as it rises, so that the name 'water-spout' is very applicable. Indeed, sometimes a spout will burst over a vessel and flood her decks with water, as a cloud-burst does a mountain side. When a spout is forming, its upper portion is often visible first, seeming to grow downwards from the clouds. By observing carefully, with a telescope, however, it will be seen that the motion in the column itself is upwards, although the moisture in the air which is rising is condensed lower and lower down, thus rendering the whirl visible lower down continually, and making it appear to be actually descending.

"On January 12, Captain Hess, American steamship Philadelphia, saw four water-spouts in latitude 36° 41′ N., longitude 72° 27′ W. On the 19th, Captain Lawson, British steamship Lizzie English, reports several a little farther to the eastward (latitude 36° 41′ N., longitude 71° 40′

W.); and from the Dutch steamship Edam, Captain van der Zee, a detailed report has been received from 3d Officer de Boerk of a large spout sighted at 7 A. M., January 21, latitude 41° 50′ N., longitude 60° 25′ W. In the last case, the spout is described as being small and straight at the base, increasing in size towards the top, where it mingled with the clouds. Ascending currents could be plainly seen; there was a strong westerly gale at the time, with occasional hail and snow; temperature of the air, 0° Centigrade; water, 11°; direction of rotation of the whirl, with the hands of a watch.

"Another very complete report has been received from Captain Dexter, American steamship City of Para, who saw several large spouts, January 22, in latitude 31° 47′ N., longitude 74° 33′ W. The wind was strong from the northeast and the sky overcast, with light scud, but the sea was comparatively smooth. Three huge spouts were seen at once, and six in the course of half an hour. The water seemed to be drawn up from the sea, mounting in spiral columns of tremendous thickness, with a loud, roaring sound. Some of the columns were vertical, some inclined at a considerable angle; all of them increased in size at the top and blended with the clouds. A fine rain or mist filled the air, and continued for some time. The wind soon after changed to east.

"Perhaps the most interesting cases of all, however, are those which were reported January 26, 27 and 28, for the reason that they were clearly associated with a low-barometer area of considerable energy, which moved across the great lakes on the 25th and was central off Nantucket on the 26th. It has been clearly shown by the United States Signal Service that when tornadoes occur on land they take place almost invariably in the southern quadrants of an area of low barometer. It might therefore be expected that whirlwinds and water-spouts would sometimes be found associated in a similar way with a cyclonic storm at sea. The following reports seem to leave no doubt that such is the case: The area of low barometer, which was central over the great lakes January 25, barometer 29.7, gathered increased energy when it reached the Atlantic, and off Nantucket the following day the barometer read 29.2, and in the gulf of Newfoundland, on the 27th and 28th, it read as low as 28.6. The cold, dry northwesterly winds in the western quadrants of this cyclone and the warm, moist air flowing into the eastern quadrants mingled to the southward of the storm center and gave rise to the conditions most favorable to the development of tornadoes on land and water-spouts at sea. Accordingly, Captain Haskell, British bark Shetland, reports that on the 26th, in latitude 39° 34′ N., longitude 71° 16′ W. (a little to the southward of the storm center), he saw a large spout; the following day (latitude 39° 12′ N., longitude 70° 44′ W.), he saw several more; and on the 28th still more. Captain Garvin, British

steamship Orinoco, reports that on the 27th, when entering the Gulf stream from the north, in about latitude 37° 20′ N., longitude 70° 40′ W., the sea was covered with thick vapor from 5 to 15 feet high. The heavy, low-lying clouds seemed to draw the vapor up, and many water-spouts were formed, both large and small; temperature of the water, 60° F.; air, 40°. Captain Cleary, British steamship River Avon, states that on the 28th, in latitude 39° 30′ N., longitude 57° 20′ W., he saw what he took to be a heavy squall to the southeast. Upon looking at it with his glass he saw that it was a whirlwind, raising the water to a great height. It must have been over a mile in diameter, but he hesitates to even estimate the height to which the water was raised or the size of the spout, although it must have had terrific power. Shortly afterwards a smaller one passed close to the ship, whirling along the water and raising the spray to a height of fully a hundred feet. Even as far south as Bermuda the conditions were the same, for on the 27th a whirlwind swept across the parishes of Southampton and Warwick, unroofing houses, blowing down trees, and damaging property generally.

"Similarly, two cyclonic storms, which seem to have originated about the Bermudas on the 10th and 12th of February, as indicated in the weather review published on the March *Pilot Chart*, were attended by water-spouts, at least one of which was disastrous to shipping. February 10, at 9 A. M., Captain Smith, British steamship Ethelbald, in latitude 28° 18′ N., longitude 74° 06′ W., reports a large spout traveling in a northeasterly direction, rotating, apparently, with the hands of a watch. The barometer was rising; fresh, variable winds, mostly southerly, and sky overcast, with very heavy rain. At this time the American bark Reindeer, Captain Strandt, was about 200 miles to the westward of the Ethelbald, running up the coast towards New York, in the Gulf stream. On the 11th, the weather became squally, with light southerly winds, and at 10:30 A. M., in latitude 32° 04′ N., longitude 76° 06′ W., when the vessel was under full sail, a heavy water-spout passed over her, completely dismasting her below the heads of the three lower masts. No previous warning was received; the weather was apparently clear at the time, and the whole affair was over in a few minutes. The dismasted vessel reached Bermuda on the 16th. Again, when the second of these two cyclonic storms was central about latitude 39° N., longitude 67° W., Captain Hogan, British schooner Alma, passed within two miles of a large spout which was traveling from west to east. This was at 2 P. M., February 14, latitude 30° 40′ N., longitude 73° 50′ W., and it was blowing a gale from N. N.W. at the time. The meteorological conditions prevalent about this time between the Bermudas and the Atlantic coast of the United States are well illustrated by a report made by Mr. Lund, British steamship Rothiemay, Captain Olsen. This vessel arrived at

Philadelphia February 20, from Montevideo. From February 1 (latitude 19° N., longitude 58° W.) to 9 (27° N., 73° W.), fine, pleasant weather with occasional showers; light to fresh breezes from southeastward. From the 9th to the 14th (34° N., 74° W.), rainy and very unsettled weather; wind mostly from southwestward, but often falling calm and flying to the opposite point of the compass, where it soon died out; thunder and very vivid lightning all around the horizon, but most marked to the N.W. and N.E. On the 13th (34° N., 75° W.), calm and light variable airs, followed by a breeze from N. N.E., which by midnight increased to a whole gale. Similarly, Captain Paine, American barkentine Henry Warner, reports that during January 21, 22 and 23, off the coast of New Jersey, he encountered light airs going around the compass two or three times every 24 hours, exhibiting this same tendency towards the formation of incipient whirlwinds and water-spouts, indicative oftentimes of a gradual generation of a great cyclonic storm.

"A still later report, and one of the best and most detailed which has recently been received, relates to a spout sighted by Captain Battle, American schooner Ethel A. Merritt. This was on February 18, latitude 24° 02′ N., longitude 81° 14′ W., in the Gulf stream, off Key West, about midway between the Florida cays and the coast of Cuba—only a week after the Reindeer had been dismasted about 500 miles to the northeastward. There was a light breeze from the northeast at the time, and the sky was about half covered with nimbus clouds, moving slowly. Just after a light squall had passed by, the first appearance of a water-spout was indicated by the formation of a whirlwind, gradually increasing in size. It was cylindrical in shape below, spreading out above and rotating in a direction with the hands of a watch. When within about 100 yards of the vessel its angular altitude was about 35°, which would indicate a height of only 250 feet, or less. It was moving to the southwest at the rate of about 8 miles an hour. At the base it was transparent, and descending currents seemed to be plainly visible, causing the water at the surface to fly in all directions. Temperature of water, 76°; of air, 83° before 78° at the time of spout, and 80° afterwards; barometer, 30.10, and fluctuating. A heavy shower of rain accompanied the spout, and the phenomenon lasted in all about 10 minutes. A brief report just received from Captain Bakker, Dutch steamship Amsterdam, states that a water-spout was sighted February 29, latitude 40° 34′ N., longitude 61° 05′ W. Weather, squally; wind, N.W.; force, 6.

"Although the study of such reports has already greatly increased our knowledge of the origin and nature of these interesting and often destructive phenomena, much yet remains to be done before we can hope to be able fully to understand the laws by which they are governed. That portion of the North Atlantic from the northern coast of Cuba to

the 40th parallel, and from the Atlantic coast of the United States to the Bermudas, is preëminently a region where water-spouts are liable to occur, owing largely to the warm, moist air which hangs over the Gulf stream, and the cool, dry air brought over it by the northwesterly winds from off the coast. A glance at the *Pilot Chart*, which shows the general course of the Gulf stream and the positions where water-spouts have been reported, indicates this fact very clearly. This great warm ocean current is now beginning to re-assert itself after a period of comparative quiescence during the winter months, and with increasing strength and volume is approaching its northern limits as the sun moves north in declination. Captain McKay, British steamship Pavonia, found a current setting his vessel 20 knots a day to the northward in latitude 42° 26′ N., longitude 57° 23′ W., January 22. Captain Gerry, American barkentine Levanter, encountered a strong current setting about N.E. by E., below Hatteras, with heavy tide rips, February 20, latitude 34° 35′ N., longitude 75° 50′ W., and again on the 24th, when 25 miles S.W. from point of Lookout shoals. Finally, Captain Freeman, American steamship Hudson, at New York, February 28, from New Orleans, reports a 5-knot current in the Gulf stream, in the straits of Florida. The warm, moist air overhanging this great 'river in the ocean,' and the cool, dry air brought down from the coast and from over the cold inshore current to the northwest, are thus the elements whose intermingling generates these dangerous whirlwinds on the ocean.

"The attention of masters of vessels is again called to the desirability of making full and accurate reports of these, as of other marine phenomena, by means of which our knowledge can be still further increased. The most important observations regarding a water-spout are the temperature of the air and water, the reading of the barometer, direction and force of the wind, and the changes which take place in each while the spout lasts. Also, the direction of rotation of the whirl, and an estimate of its size, character, and changes of form, with, if possible, sketches, however rough, of its appearance at the various stages of its formation and progress. Many naval vessels are now provided with photographic apparatus, and portable cameras are in such common use by travelers that it may not be too much to expect that advantage will be taken of some favorable opportunity to secure instantaneous photographs from the deck of a vessel to illustrate these remarkable phenomena. Such photographs would be of the greatest value and interest to this Office."

To the above paper we make the following addition, which was kindly communicated from the division of Marine Meteorology of the Hydrographic Office:

With the *Pilot Chart* for March there was issued a supple-

ment containing a chart, showing the positions where more than thirty water-spouts had been reported during January and February off the Atlantic coast of the United States, with descriptions furnished by masters of vessels. It was also pointed out what an important factor the Gulf stream is in the formation of water-spouts off our coast, the warm moist air overhanging this great ocean current mingling with cooler drier air brought down by northwesterly winds from off the coast, and giving rise to the conditions which are known to be favorable to the development of water-spouts, tornadoes, and even of great cyclonic storms. The great storm which swept the coast from the 11th to the 15th of March, has lent additional interest to studies of the meteorological conditions which give rise to such destructive cyclones, and to the question as to the possibility of predicting them with greater certainty then has been done hitherto. Endless discussions have taken place, and volumes have been written regarding the effect of the Gulf stream in modifying the climate of northern Europe, while comparatively little attention has been devoted to its vitally important influence upon the climatic conditions of our own Atlantic sea-board. For this reason the following additional data, received since the publication of the supplement referred to above, have been compiled for publication. Brief mention was made of a water-spout sighted by Captain Bakker, Dutch steamship, "Amsterdam," February 29th, lat. 40° 34′ N., long. 61° 05′ W. A detailed report received subsequently gives the following additional particulars: The time was 9:50 P. M., Greenwich mean time, and the estimated distance of the spout, about three miles. It was travelling with the wind, which was northwest, force 6, and rotating in a direction with the hands of a watch. The sky was overcast with dark nimbus clouds, accompanied by squalls of hail and snow at intervals, though not at the time the spout was seen, nor was there any shift of wind. The temperature of the air before, after, and at the time of spout, was 30°, 31° and 28°, respectively. Barometer 29.39° (corrected) and rising at the rate of about .02° an hour.

Captain Grey, Br. S. S. Earnmoor, reports that more than

thirty water-spouts passed his vessel February 12th, some of them coming very near. His position at the time was lat. 35° N., long. 74° 45′ W., about 50 miles E.S.E. from Hatteras. It will be remembered that about this date water-spouts were sighted from the Br. S. S. "Ethelbald" and schooner "Alma," farther to the southward, where, also, the American bark "Reindeer" had been dismasted only a day previously.

Captain Brunn, Nor. steamship "Fædrelandet," when in lat. 28° 15′ N., long. 68° 10′ W., February 20th, observed a large spout travelling to the northward and eastward. Wind E.S.E., force 3; temperature of the air, 73°; water, 72°; barometer, 30.25° (corrected). Also, March 14th, between 4 and 8 A. M. (ship's time), lat. 34° 50′ N., long. 74° 41′ W., to lat. 35° 63′ N., long. 74° 41′ W., observed a number of small spouts, probably twenty or thirty. They were travelling with the wind, which was blowing a heavy gale from N.N.W., and rotating in a direction opposite to the motion of the hands of a watch. The weather was threatening and stormy looking, with very wet fog. Temperature of the air, 46°; water, 72°. Barometer, 29.72° (corrected). This last report is especially interesting when considered in connection with the following report, received from Captain Bermpohle, Br. S. S. "Samana," who was about 60 miles to leeward of the "Fædrelandet," and who reports that on March 14th, lat. 34° 10′ N., long. 74° 16′ W., he observed many water-spouts between 8 A. M. and noon. It will be noticed that both vessels were in the southwest quadrant of the storm which had just passed up the coast with such destructive violence, and was then central off Nantucket. A cold northwesterly gale was blowing over the warm Gulf stream current, and the water-spouts sighted by Captain Brunn near the western edge of the stream were evidently associated with those sighted a few hours later by Captain Bermphole, 60 miles to leeward. An excellent detailed report made out by 1st Officer O'Brien, of the "Samana," gives many interesting particulars regarding the spouts sighted from that vessel. They were of different sizes, all ascending with a spiral motion to the clouds, and then disappearing. One came within about a mile of the ship, and they were all within from one to

three miles. They appeared to rotate in a direction against the hands of a watch, and were travelling in a southerly direction. There was a strong gale from west, hauling to northwest, with occasional snow, and a blinding spray flying over the vessel. Clouds, cirro-cumulus and stratus. Temperature of water, 74°.

The only remaining reports at hand from vessels in the western portion of the North Atlantic during the past three months are as follows: Captain Lang, Br. S. S. "Counsellor" states that two large whirlwinds or water-spouts passed from the eastward to the westward about half a mile from his vessel, February 25th, lat. 44° 31′ N., long. 37° 33′ W. And Captain Ueberweg, Belgian S. S. "Switzerland," saw a large water-spout March 11th, lat. 39° 52′ N., long. 53° 10′ W. The wind had been baffling and the weather showery. It began to show signs of clearing to the southwest when the spout was observed coming down from the northeast. When about three miles from the vessel it burst, causing considerable disturbance on the water. In the supplement to the March *Chart* data were also given, showing that a strong current had been observed in the Gulf stream, and that it was rapidly resuming its normal summer strength and limits. The following reports confirm those already quoted:

Captain Barstow, American bark "James S. Stone," reports as follows:

March 19th, lat. 36° 12′ N., long. 73° 17′ W., crossed the inner edge of the Gulf stream, which was very clearly defined as far as the eye could reach. The current itself, running about E.N.E., could be easily distinguished, flowing past the colder wall of water along its western boundary. The wind at the time was very light and the sea smooth.

Captain Gates, American brig, "Arcut," reports that on March 17th, he found a band of warm Gulf current, temperature 75°, lat. 35° 02′ N., long. 70° 05′ W., to lat. 35° 20′ N., long. 71° 35′ W., setting to the *southwestward*, with a band of cold water (temperature 45°) between it and the main stream, which seemed to be some sixty miles to the southeast of its usual position.

Such reports relative to the strength, direction, and position of the Gulf stream current, are always of great interest, and are constantly referred to in the work of the Hydrographic Office. Masters of vessels are therefore urged to make full notes of current observations and forward them to the Branch Hydrographic offices with their meteorological observations.

CORRESPONDENCE.

BAROMETRIC CHANGE DURING SOLAR ECLIPSES.

To the Editors: After reading Messrs. Upton and Rotch's note upon this subject in the *American Meteorological Journal* for February, it occurred to me to turn to Mr. Glaisher's report of the annular eclipse of March 15, 1858, my first (and last) solar eclipse expedition. It forms an appendix to the report of the council of the British Meteorological Society for the year ending June, 1858. Table V gives barometer readings each 15 minutes, from 9 A. M. to 3 P. M. (middle of eclipse, 1 P. M.), at twenty stations. Some of them omitted various readings, but nine were perfect for 1¼ hours on each side of central eclipse. I copied out the figures and have also plotted them, reproducing at the bottom the Chlamostino record for comparison. I see that Mr. Glaisher in the report in question says, "No special remark is needed upon this table, there being no special change of readings which can be attributed to the eclipse." In a little pamphlet which I wrote in 1860* I find an analogous paragraph. "The barometer does not appear to have been affected to any appreciable extent; it fell towards the totality in Spain, it slightly slackened in its downward march at Little Bredy, and it rose an infinitely small quantity at Silloth." Now that these have been followed by the Chlamostino observations, it seems to me that eclipse observers may safely leave their barometers at home.

G. J. Symons.

62 Camden Square, London, England.

P. S.—I have just found another set of readings, taken during

* Notes on the Solar Eclipse of July 18th, 1860, by G. J. Symons.

a large partial solar eclipse in London, July 8th, 1842, (middle of eclipse, 5:45 A. M.), and have added them to the table and diagram.* They are given in the *Quarterly Journal of Meteorology*, but I do not see that they throw further light on the subject.

TORNADOES AND CYCLONES.

TO THE EDITORS: An interesting question has recently arisen as to the first mention of the fact that tornadoes do not occur at the center, but rather in the southeast quadrant of an area of low pressure. From time to time statements have been made regarding this subject, and Professor Ferrel, in "Recent Advances," page 327, considers that this point was first brought out in Professional Paper of the Signal Service, No. VII. On examining this, however, we find the author considers that tornadoes occur in the *southwest* quadrant of a low area. A discussion of this question by Professor Davis will also be found in this journal for August, 1884. The following extract is from a paper published in the Washington *Post*, March 30th, 1884. The paper was written March 15th, and sent *Science*, but it was refused as being a criticism on Prof. Davis' article in that journal It may be wisé to give it a more permanent form for reference:

* The diagram is not reproduced; the table is as follows:

PARTIAL ECLIPSE, JULY 8, 1842.		ANNULAR ECLIPSE, MARCH 15, 1858.									
Time.	London.	Time.	Stonyhurst, Lancashire.	Birmingham, Warwick.	Teignmouth, Devon.	Oundle, Northampton.	Little Bredy, Dorset.	Holkham, Norfolk	Lewisham, Kent.	Greenwich, Kent.	Battersea, Surrey.
A. M.		11.45	29.490	29.500	30.056	29.749	29.645	29.850	29.912	29.815	29.988
4.45	29.825	Noon.	.494	.510	.058	.750	.651	.846	.912	.832	.994
5.0	.830	0.15	.497	.510	.054	.749	.654	.852	.914	.839	30.000
.15	.845	.30	.498	.512	.054	.751	.655	.864	.916	.843	.008
.30	.850	.45	.500	.513	.058	.750	.652	.866	.920	.850	.014
.45	.850	1.0	.500	.512	.054	.749	.648	.868	.936	.850	.012
6.0	.850	.15	.506	.501	.060	.756	.647	.870	.924	.850	.006
.15	.850	.30	.502	.500	.065	.755	.641	.864	.924	.850	29.998
.30	.850	.45	.497	.500	.064	.759	.645	.870	.918	.849	30.008
.45	.850	2.0	.494	.500	.064	.752	.651	.876	.917	.849	29.998
7.0	.850	2.15	.492	.500	.068	.763	.652	.872	.921	.849	30.002

"THE ORIGIN OF A TORNADO.

* * * * Another theory is that tornadoes occur where there are great contrasts of temperature in warm southerly and cooler northerly winds. This theory is partly based on the supposition that tornado action occurs near the center of a storm. It is admitted that immediately on either side of a storm center there are strong contrasts of temperature, and there is a partial meeting of warm southerly and cooler northerly winds, but there are no tornadoes at or even near that point. Let us take a map of any region having upon it, very near the time of the tornado, lines of equal pressure and temperature and directions of the wind. There will invariably be upon it a storm-center. Through the center of this draw a line from southwest to northeast, and we shall find on the northwest side low temperature and cold and dry northwest winds, due to an advancing high area. On the southeast side, however, the air is laden with moisture and is hot, there are frequent rains, and well nigh uniform southerly winds. If now we project the tornado tracks upon the map we shall find them in the region to the southeast, and generally hundreds of miles from the storm-center, and where there are no northerly winds. A critical study of tornado tracks upon a weather map will develop these points in nearly every instance. Frequently there are in the tornado region higher temperatures to the north than in the south, and very seldom will there be a lowering of temperature from south to north, any greater than the constant difference due to the difference in latitude. * * * * *

In seeking for a probable solution of the problem we have, to-day, a powerful adjunct in the weather map showing at any hour of the day the precise conditions existing over the region of tornado action. An examination of such a map will show that the most persistent factor is the storm-center, which always exists to the northwest and north, 300 or more miles away. * * * * *

The signs of probable tornado action may be enumerated as follows:

1st. There must be a storm-center fairly well marked, though this may be 600 or 700 miles away. Tornadoes almost invariably occur to the south and southeast of this point.

2nd. It is believed that the temperature in the above region should be above the mean. Great contrasts of temperature are not necessary, and if, in connection with them, an area of high pressure is found to the northwest or west, no tornado will ordinarily occur.

3rd. In general the air should be moist.

4th. As extended thunder-storm action is an invariable accompaniment of a tornado, it is believed that these may give some indications of more severe action."

H. A. HAZEN.

CURRENT NOTES.

CORRECTIONS.—Page 392, 17th line, for Freenwich read Greenwich; page 397, 8th line, for This image . . . needle had, read There is also a reflected image of the cross wires to be seen in the mercury; page 399, 2d line, for $2^{mm.}$ $0.2^{mm.}$

JAPANESE METEOROLOGY.*—This annual volume of Japanese meteorology is particularly interesting, showing as it does by means of charts and tables the meteorology of the long narrow chain of islands lying at a distance from the main land. Japan affords an unusual opportunity for investigating the effects of the ocean or climate, where the exposure is on the leeward coast as regards the approach of storms. (Great Britain lying to the windward of the mainland).

In this volume of 86 pages we find: the position of the Meteorological and Signal stations; the areas of low barometer with tracks of centers; the areas of high barometer with tracks of centers; the lowest and highest pressures and temperatures; the frequency of gales for each direction; the days of the month with gales observed; heavy rains; storm warnings issued; verification of these warnings and indications; and the gales observed at light-houses. The maps of isobars, isotherms and prevailing winds, and monthly and yearly tables of mean pressure, temperature and rainfall. Charts of monthly and annual precipitation, and finally, the Monthly Weather Review.

Following the example of Russia (which uses Russian and German) the headings of tables and text are printed in Japanese and English. The centigrade and meter scales are used.

It would seem, however, that either a rich supply of sea observations must be available, or else a good deal of uncertainty must exist as to the correctness of locations assigned as the centers of highs and lows. F. W.

ROYAL METEOROLOGICAL SOCIETY.—The usual monthly meeting of this Society was held on Wednesday evening, March 21, at the Institution of Civil Engineers, 25 Great George Street,

*Monthly Summaries and Monthly Means for the year 1886, with 41 Maps. Imperial Meteorological Observatory, Tokio, Japan.

Westminster, Dr. W. Marcet, F. R. S., President, in the chair.

Dr. G. E. Scholefield and Col. W. S. Young, were elected Fellows of the Society.

The President (Dr. Marcet) delivered an address on Atmospheric Electricity. He first alluded to Franklin's experiments in America in 1752, who succeeded in obtaining the electricity of a storm-cloud by conducting it along the string of a kite sent into the cloud. De Romas, in Europe, repeated the experiment, and having placed a wire within the twine his kite was attached to, obtained sparks of nine or ten feet in length. The characters of the two kinds of electricities were not described, the vitreous or positive, which was produced by rubbing glass, and the resinous or negative obtained by rubbing sealing wax or another resinous substance; and it was shown by bringing suspended balls of pith within the influence of these electricities, that electricities of different kinds attract each other, and those of the same kind repel each other. De Saussure's and Volta's electroscopes were next described, pith balls being used in the former and blades of straw in the latter, for testing the pressure of electricity. With the object of measuring the force of electricity, Sir W. Thomson's electrometer was mentioned, in which the electricity is collected from the air by means of an insulated cistern letting out water drop by drop, each drop becoming covered with electricity from the atmosphere, which runs into the cistern where it is stored up, and made to act upon that portion of the instrument which records its degree or amount. The atmosphere is always more or less electrical, or in other words, possessed of electrical tension, and this is nearly always positive, while the earth exhibits electrical characters of a negative kind. The effects of atmospheric electricity were classed by Dr. Marcet under three heads. 1st. Lightning in thunder-storms; 2nd. The formation of hail; 3rd. The formation of the Aurora borealis and australis. He explained how clouds acquired their electrical activity by remarking that clouds forming in a blue sky, by a local condensation of moisture, became charged with positive electricity from the atmosphere; while heavy dark clouds rising from below nearer to the earth were filled with

terrestrial negative electricity, and the two systems of clouds attracting each other would discharge their electricity, giving rise to flashes of lightning. In some cases a storm-cloud charged with positive electricity would approach the earth, attracting the terrestrial negative electricity, and when within a certain distance shoot out a lightning which would apparently strike the earth; but it would just as well have struck the cloud, only there was nothing in the cloud to sustain any damage, while on the earth there were many objects lightning would destroy, to say nothing of its effects upon animal life. Thunder is the noise produced by the air rushing in to fill up the vacuum made by the heat of the lightning flash. There may be sheet lightnings, zig-zag, or forked lightnings, and globular lightnings. The latter are particularly interesting from their assuming a spherical form. Illustrations were given of objects struck by lightning, the most remarkable being, perhaps, the clothes of a working man which were torn into shreds, while the man himself was not seriously injured. Dr. Marcet next proceeded to show a flash of lightning, which he produced by throwing on a white screen the image of an electric spark, two or three inches in length, enlarged by means of the lens of an optical lantern; forked lightning, six or eight feet in length, with its irregular zig-zag course, was most clearly demonstrated. After alluding to the protecting power of lightning conductors, and their construction, Dr. Marcet explained the formation of hail and of water-spouts, and exhibited an instrument by Professor Colladon, of Geneva, for showing the formation of water-spouts. He concluded his address with a few remarks on the Aurora borealis and australis, the formation of which was illustrated by de la Reve's experiment, which consisted of successive discharges of electric sparks through a partial vacuum while under the influence of a powerful magnet; electric sheets of light were seen assuming the form of bands and possessed of a certain rotating motion.

Mr. G. J. Symons, F. R. S., read a short communication on "The Non-existence of Thunderbolts," and briefly described the history of several so-called thunderbolts, the specimens ob-

tained being of an amusing character, thus clearly showing that they were of a terrestrial and not a celestial nature.

In connection with this meeting a most interesting exhibition of instruments was arranged in the rooms of the Institution of Civil Engineers. The exhibition was devoted chiefly to instruments connected with atmospheric electricity. There were various forms of electrometers, including those formerly in use at the Greenwich and Kew observatories. Numerous patterns of lightning conductors were exhibited, together with models of churches, houses, chimney-shafts, and ships, showing the various methods of protection. The Postal Department showed a number of lightning protectors used for telegraph purposes. Many objects damaged by lightning were exhibited, including lightning conductors, telegraph apparatus, portions of rafters, trees, etc., also the clothes of a man torn off his body by lightning. An interesting collection of meteorites and some alleged thunder-bolts were shown, the latter being of an amusing character. There were also several new meteorological instruments exhibited, which had been brought out during the past twelve months.

One of the special features of the exhibition was a most valuable and interesting collection of over fifty photographs of lightning flashes. Many of these were taken during the great thunder-storm which occurred in London on August 17th, last year, while others were taken in various parts of the world.

The exhibition also included a large number of photographs of damage by lightning, and photographs of clouds and meteorological instruments, as well as records of atmospheric electrictiy, etc.

Relation Between Tropical and Extra-Tropical Cyclones.—The following conclusions as to the relation of tropical to extra-tropical cyclones are derived by the Hon. Ralph Abercromby from his researches, as given in a paper read before the Royal Society.

Cyclones have a tendency to assume an oval form; the longer diameter may lie in any direction, but has a decided tendency to range itself nearly in a line with the direction of propagation.

The centre of the cyclone is almost invariably pressed towards

one or other end of the longer diameter; but the displacement may vary during the course of the same depression.

Tropical hurricanes are usually of much smaller dimensions than extra-tropical cyclones; but the central depression is much steeper and more pronounced in the former than in the latter.

Tropical cyclones have less tendency to split into two, or to develop secondaries, than those in higher latitudes.

A typhoon, which has come from the tropics, can combine with a cyclone that has been formed outside the tropics, and form a single new, and perhaps more intense, depression.

No cyclone is an isolated phenomenon; it is always related to the general distribution of pressure in the latitudes where it is generated. The concentric circles, which are usually drawn to represent a cyclone, ignore the fact that a cyclone is always connected with and controlled by some adjacent area of high pressure.

In all latitudes pressure often rises over a district just before the advent of a cyclone. The nature of this rise is at present obscure; but the character of the unusually fine weather under the high pressure is identical both within and without the tropics.

In all latitudes a cyclone which has been generated at sea appears to have a reluctance to traverse a land area, and usually breaks up when it crosses a coast line.

After the passage of a cyclone in any part of the world there is a remarkable tendency for another to follow very soon, almost along the same track.

The velocity of propagation of tropical cyclones is always small and the average greatly less than that of European depressions.

There is much less difference in the temperature and humidity before and after a tropical cyclone than in higher latitudes. The quality of the heat in front is always distressing in every part of the world.

The wind rotates counter-clockwise round every cyclone in the northern hemisphere; and everywhere as an in-going spiral. The amount of incurvature for the same quadrant may vary during the course of the same cyclone; but in most tropical hurricanes the incurvature is least in front, and greatest in rear, whereas in England the greatest incurvature is usually found in

the right front. Some observers think that, broadly speaking, the incurvature of the wind decreases as we recede from the equator.

The velocity of the wind always increases as we approach the central calm in a tropical cyclone; whereas in higher latitudes the strongest winds and steepest gradients are often some way from the centre. The portion of a cyclone which is of hurricane violence forms, as it were, a kernel in the centre of a ring of ordinary bad weather. In this peculiarity tropical cyclones approximate more to the type of a whirlwind tornado; but the author does not think that a cyclone is only a highly developed whirlwind, as there are no transitional forms of rotating air.

The general circulation of a cyclone, as shown by the motion of the clouds, appears to be the same everywhere.

All over the world unusual coloration of the sky at sunrise and sunset is observed not only before the barometer has begun to fall at any place, but before the existence of any depression can be traced in the neighborhood.

Cirrus appears all round the cloud area of a tropical cyclone, instead of only round the front semicircle as in higher latitudes. The alignments of the stripes of cirrus appear to lie more radially from the centre in the tropics, instead of tangentially to the isobars, as indicated by the researches of Ley and Hildebrandsson in England and Sweden respectively.

The general character of the cloud all round the centre is more uniform in than out of the tropics; but still the clouds in rear are always a little harder than those in front.

Everywhere the rain of a cyclone extends farther in front than in rear. Cyclone rain has a specific character, quite different from that of showers or thunderstorms; and this character is more pronounced in tropical than in extra-tropical cyclones.

Thunder or lightning are rarely observed in the heart of any cyclone, and their absence is a very bad sign of the weather. Thunderstorms are, however, abundantly developed on the outskirts of tropical hurricanes.

Squalls are one of the most characteristic features of a tropical cyclone, where they surround the centre on all sides; whereas in Great Britain squalls are almost exclusively formed along that portion of the line of the trough which is south of the centre, and in the right rear of the depression. As, however, we find that the front of a British cyclone tends to form squalls

when the intensity is very great, the inference seems justifiable that this feature of tropical hurricanes is simply due to their exceptional intensity.

A patch of blue sky in the centre of a cyclone, commonly known as the "bull's-eye," is almost universal in the tropics, and apparently unknown in higher latitudes. This blue patch does not apparently always coincide exactly with the barometric centre. The author's researches show that in middle latitudes the formation of a bull's-eye does not take place when the motion of translation is rapid; but as the blue space is not observed in British cyclones when they are moving slowly, it would appear that a certain intensity of rotation is necessary to develop this phenomenon.

The trough phenomena—such as a squall, a sudden shift of wind and change of cloud character and temperature just as the barometer turns to rise, even far from the centre—which are such a prominent feature in British cyclones, have not been even noticed by many meteorologists in the tropics. The author, however, shows that there are slight indications of these phenomena everywhere; and he has collated their existence and intensity with the velocity of propagation of the whole mass of the cyclone.

Every cyclone has a double symmetry. One set of phenomena such as the oval shape, the general rotation of the wind, the cloud ring, rain area, and central blue space, are more or less related to a central point. Another set, such as temperature, humidity, the general character of the clouds, certain shifts of wind, and a particular line of squalls, are more or less related to the front and rear of the line of the trough of a cyclone.

The author's researches show that the first set are strongly marked in the tropics, where the circulating energy of the air is great and the velocity of propagation small; while the second set are most prominent in extra-tropical cyclones, where the rotational energy is moderate and the translational velocity great.

The first set of characteristics may conveniently be classed together as the rotational; the second set as the translational phenomena of a cyclone.

Tropical and extra-tropical cyclones are identical in general character, but differ in certain details due to latitude, surrounding pressure, and to the relative intensity of rotation and translation.

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